This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U.S. Department of Energy.

Application of Non-Spherical Fissile Configuration in Waste Containers at SRS

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INTRODUCTION

Transuranic (TRU) solid waste that has been generated as a result of the production of nuclear material for the United States defense program at the Savannah River Site (SRS) has been stored in more than 30,000 55-gallon drums and carbon steel boxes since 1953. Nearly two thirds of those containers have been processed and shipped to the Waste Isolation Pilot Plant. Among the containers assayed so far, the results indicate several drums with fissile inventories significantly higher (600 – 1000 fissile grams equivalent (FGE) ^{239}Pu) than their original assigned values. While part of this discrepancy can be attributed to the past limited assay capabilities, human errors are believed to be the primary contributor.

This paper summarizes the application of non-spherical fissile material configuration in waste containers, resulting in less restrictive mass and spacing limits, increased storage capacity, and several administrative controls for handling and storage of waste containers being modified without compromising safety.

DISCUSSIONS

Conservative criticality safety calculations for TRU waste containers, assuming fissile material in an optimally moderated spherical configuration inside containers, resulted in a historical subcritical mass limit of 195 FGE ^{239}Pu per container for storage of most TRU waste containers in an array of containers. Furthermore, criticality safety margins were included in the operating procedures at the generator facilities to ensure the subcritical mass limit was not violated.

The subcritical mass limit was established based on the assumption that other parameters such as moderation, fissile material concentration, reflection, geometry, and neutron absorber content were at their optimum conditions for reactivity for every container in the array. Such restrictive subcritical limit would have been sufficient for handling and storage of waste containers had there been no human errors or underestimated assay results involved in generating waste containers exceeding 195 FGE ^{239}Pu.

A recent statistical analysis of 5,600 waste drums [1] determined that the generators consistently, but not exclusively, overestimated the fissile content of those drums. While the assay results of waste drums using the current assay techniques indicate that the majority of drums have much less than 195 FGE ^{239}Pu, in agreement with the generators' original assigned values, a fraction of the drums have exceeded the subcritical mass limit by as much as 50%. Additionally, the assay results have identified several drums with fissile inventories between 600 and 1000 FGE ^{239}Pu.

Moderation was assumed to be optimized (as light water) in obtaining the subcritical mass limits. Most of the moderator in waste is from plastic packaging and bag-out sleeves although there is the potential for some water in-leakage to the packages during storage. A past study at SRS demonstrated that no more than 20 volume percent of a container could be hand packed with plastic sheeting [2]. Thus, the hydrogen density in a waste matrix is considerably less than that of the full density water assumed in developing subcritical limits. For waste containers that have not been exposed to rain-water during storage, the actual hydrogen density in a waste package provides a safety margin.

Neutron absorbers present in the waste also provide an additional safety margin. A past study [3] of the amounts of polyethylene in a waste container indicates that 14.5% of the waste total weight is due to polyethylene and 22.3% due to polyvinyl chloride (PVC). The chlorine in the PVC is a neutron absorber.

The waste containers have been exposed to various configurations and conditions since being packaged. These containers have been exposed to various types of interaction with other fissile material and reflection from other TRU waste containers, forklifts, personnel, etc. Some waste drums were buried underground and some drums and steel boxes were exposed to rain water during storage. Despite the excess fissile content of some containers, the containers have remained subcritical because not all the conditions, such as moderation, fissile material concentration, reflection, geometry, and neutron absorber content, are in the ranges required to support a critical configuration.

Compliance with the historical subcritical mass limit of 195 FGE ^{239}Pu would require that containers shown to have a fissile mass exceeding 195 FGE ^{239}Pu be isolated from other fissile material, which severely hampers processing and shipment of waste containers.

New calculations were performed to obtain less conservative storage limits. The fissile material configuration inside waste drums was assumed to be a short cylinder (pancake) at the bottom of the drum with a diameter equal to that of the drum internal diameter. The fissile material configuration inside steel boxes was assumed to be a slab at the bottom of the steel box with lateral dimensions equal to the box internal dimensions. The bases for such assumptions are presented below.

A waste packaging practice study [4] concluded that fissile material inside the waste containers is randomly distributed regardless of the source of the material, the waste generator, or when the waste was placed in a container. Given that fissile material in waste is randomly distributed upon packaging, it is reasonable to assume that the randomly arranged fissile material, in the absence of any means inside the containers to agitate the waste and accumulate the fissile material in one region, would not be able to arrange itself in an optimal geometry configuration (i.e., a sphere). Thus, it is conservative to assume that as rain-water enters the container from the top it may wash the fissile material to the bottom of the container. As the water level rises at the bottom of the container over time, it mixes with fissile material to form a cylinder or slab, depending on the container's geometry.

Rain water could have entered a container only through the venting filters or other small penetrations. Rain water dripping to the bottom would tend to follow the same paths to the bottom of the container, bypassing much of the plutonium in the container. Also, at least a portion of the fissile material that is attached to the waste is expected to remain attached to the waste even if in the drip paths. Furthermore, much of the fissile material in many of the waste containers is contained in plastic bags and other containers, which would inhibit settling to the bottom of a container. Thus, formation of fissile material into an optimally moderated sphere is deemed unrealistic, and the most credible, yet conservative, configuration is a cylinder or a slab at the bottom of a continuer.

Waste placed into the majority of waste containers may have been job control waste or process waste. Job control waste comes from work areas surrounding the process lines and consists of items used outside the process lines that have become contaminated because of trace amounts of fissile material. Process waste has a higher fissile content than job control waste, but it does not contain excessive amounts of fissile material because of nuclear material accountability, ALARA, and the container inventory restrictions imposed on the waste generators. Process waste may include hand tools, lead lined gloves, glovebox HEPA filters, plastic bottles containing swipes used to clean out cabinets, suits and hoses, absorbent, coveralls, brushes, metal cans, scrap metal, nuts, bolts, washers, cardboard, plastics, tapes, etc. These items are considered contaminated because of contact with trace amounts of fissile material.

While the fissile material configuration is assumed to collect at the bottom of the containers in a non-spherical configuration, the obtained limits are conservative in that other parameters such as moderation, fissile material concentration, reflection, geometry, and neutron absorber content are assumed at their optimum conditions for reactivity for every container in the array.

CONCLUSION

The assumption of a non-spherical fissile material configuration inside the waste containers resulted in less restrictive mass and spacing limits, increased storage capacity, and several administrative controls for handling and storage of waste containers being modified without compromising safety.

REFERENCES

1. J. Myers, and W. Chromec, "Statistical Analysis of NDA Data," WSMS-LIC-M-05-0027, October 2005.
2. R. C. Hochel, et. al., "Nuclear Safety of Plutonium /Polyethylene Waste in TRU Culverts," DPST-88-1014, December 1988.
3. D. W. Murdoch, "TRU Drumliner Polyethylene Estimate," February 1988.
4. A. Q. Goslin, "Waste Generator Actions in Support of the Solid Waste Double Contingency Analysis," ECS-CRT-97-0026, 1997.